Essential Atmospheric & Oceanographic Measurements in Hard to Reach Areas of the Battlespace

by

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Abstract

Understanding the environmental effects on weapons systems in all dimensions of the battlespace is essential to effective employment of those weapons. Understanding is based on data -- data which may not be available when really needed. Weather satellites provide an important overall view of the atmosphere and ocean and make may of the measurements used in numerical models which analyze and predict future status. Surface based in-situ and remote sensing devices help fill in many of the voids in the data base. But, there are large regions of the world which do not have adequate coverage and during combat there are many areas where data are denied or impractical to measure with conventional instruments. The US Navy's Naval Research Laboratory has embarked on a campaign to refine our capability to fill the data gaps in the Battlespace, particularly in fulfilling the need for mesoscale measurements near the ocean-atmosphere interface, One such effort has been support for the demonstration of a new miniaturized GPS-based sensor platform which promises to provide a broad range of applications. This paper describes the development and testing of the first versions of this device which measures temperature, pressure, humidity and winds from a package that is 1.5" in diameter and 8.1" long for deployment from standard countermeasures dispensing systems. Initial demonstrations were conducted using an EA-6B and a P-3 aircraft. Follow-on demonstrations are scheduled on the SH-60 helicopter, the Predator UA V, and other aircraft. Results of these demonstrations are presented along with future plans for oceanographic, rocket propelled, and surface implant deployments and integration of additional sensor types. The significance of this development is that these instruments can be launched from almost any m ilitary and many civilian aircraft equipped with standard countermeasures dispensing systems without any modification to the aircraft Data can be received on board the aircraft, via satellite links, or by surface based receivers and input to fine scale and large scale models for various applications. Some of these applications are presented in the paper.

1. Overview

Meteorological satellites provide excellent broad scale coverage of weather patterns and deliver very good estimates of some of the meteorological data elements needed to predict the future state of the atmosphere. The worldwide upper air observing system supplements satellite observations with data from radiosondes and other instruments. Data collected from this network of satellite and surface based systems feed the numerical weather forecast models of the world's meteorological centers. Unfortunately there are gaps in the data base caused by several factors. In the case of the satellites, they lack the spatial and temporal resolution required for some forecasts and for others they are inhibited from making required measurements by intervening atmospheric phenomena or deficient technological capability. The surface based systems are limited in filling the

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void because large areas of the earth are covered by water or are sparsely inhabited and thus not ideal for radiosonde or other types of observing systems. Finally, when political or combatant conflicts occur, conventional weather data -- both satellite and surface based -- are often denied or otherwise not readily available. Thus, there is a valid need for further supplementing the data base with other sources. The US Navy's Naval Research Laboratory is sponsoring a tactical dropsonde program to demonstrate a method for obtaining essential atmospheric measurements in hard to reach areas of the combat zone -- otherwise known as "the battlespace". This paper describes a unique Global Positioning System (GPS) based instrument which has been initially designed to be employed as a dropsonde but which has many other potential applications.

2. Dropsonde History

Current dropsondes which use Omega or Loran navigation systems for winds evolved from earlier versions which measured pressure, temperature and humidity (PTH) only. The US Air Force Hurricane Hunters employ a National Center for Atmospheric Research (NCAR) designed dropsonde which uses the Omega system for winds. It measures 16 inches in length, has a circular cross-section which is 3.5 inches in diameter and it weighs about one pound. It is deployed from WC-1 30 aircraft by means of a specially designed tube mounted in the floor of the aircraft cargo compartment. The Navy's objective in sponsoring a tactical dropsonde program was to employ a design which could be deployed from many different aircraft without significant aircraft modification. Their approach was to demonstrate a "tactical dropsonde" deployed from standard countermeasures dispensing systems (CDMS), normally used for chaff and flare dispensing.

3. Tactical Dropsonde Development

The Naval Research Laboratory (NRL) Center for Tactical Oceanographic Warfare Support (TOWS) Program Office contracted with Neptune Sciences, Inc. (NSI) and its two subcontractors, Tracer Aerospace and Radian International Electronics Division to demonstrate this capability. The contractor team embarked on internally financed independent research and development (IRAD) design and development activity to come up with a completely new miniaturized, ruggedized dropsonde capable of deployment from standard CDMS, able to survive the harsh operating environment, and able to measure critical atmospheric elements. Phase 1 of the effort resulted in the successful demonstration of a PTH-Only dropsonde such as the one depicted in Figure 1.

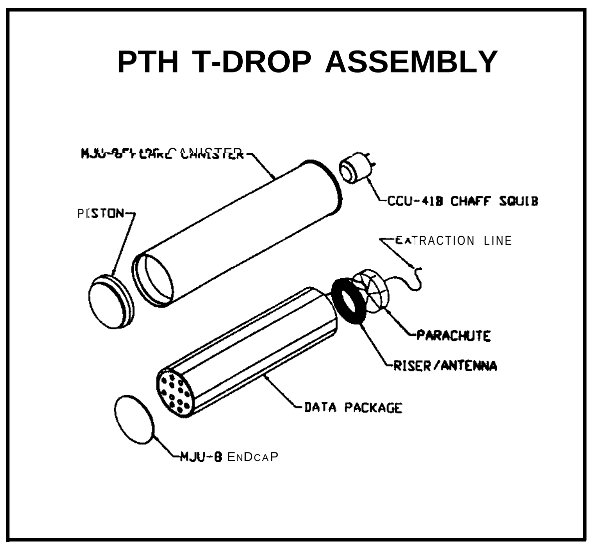

Figure 1.

On **29** Feb 1996 an operational EA-6B from VAQ-1 39, Whidbey Island NAS, WA, successfully deployed several PTH TDrop™ (for tactical dropsonde) units off the coast of Washington near Ocean Shores.

Figure 2 depicts the ejection sequence.

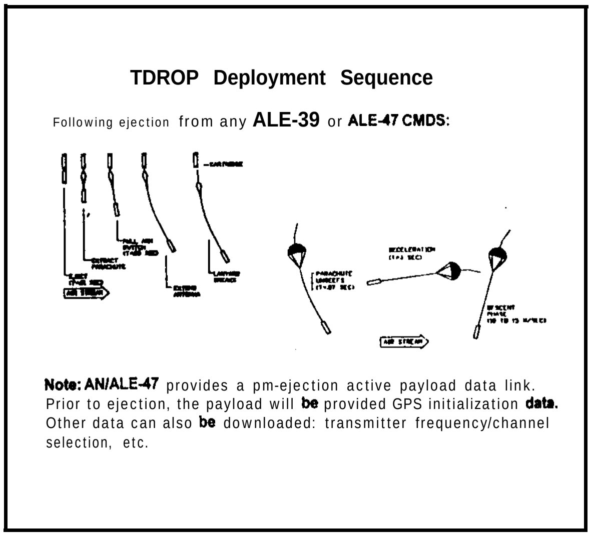

Figure 2.

Data were received by a ground based receiver stationed on the shoreline some 5-10 miles from the drop point. While this was an uncalibrated demonstration, data from the upper air site at Quillayute (UIL) are shown in figure 3 along with data from one of the TDrop™ deployments. UIL is a land based site 70 miles north of the drop point and the data were observed some 3 hours prior to the drop. The temperature inversion evident at UIL was most likely not present over the water at the drop site, thus making for a relatively good comparison between the radiosonde and the dropsonde data. The most important aspect of the demonstration was that the sonde survived ejection from the CDMS after experiencing extreme temperatures and vibrations while captive in the EA-6B's CDMS prior to launch. Following this initial success, the contractor

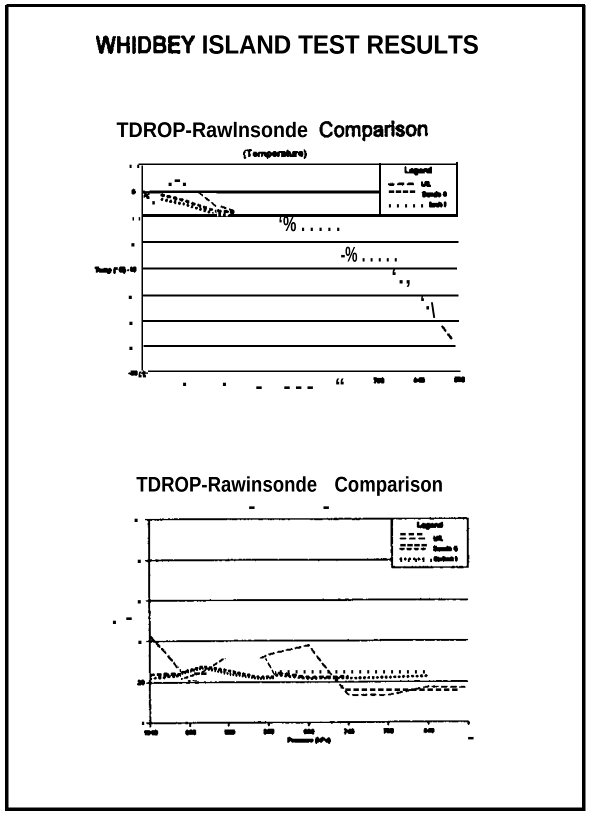

Figure 3.

team embarked on further internally financed IRAD design and development of a GPS based TDrop™.

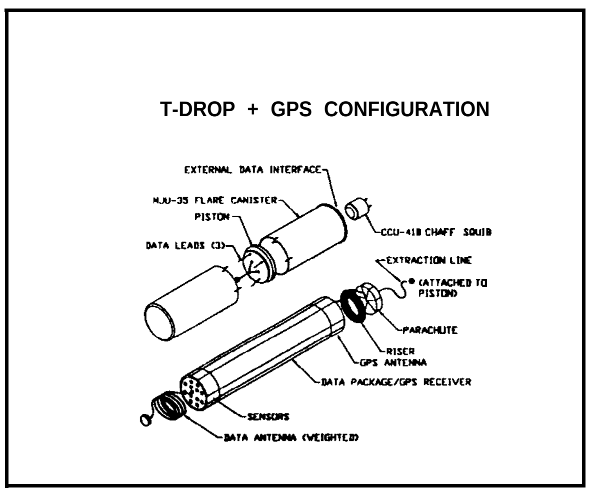

Figure 4.

This has resulted in initial prototypes similar to the one depicted in Figure 4. As this paper was being written, the prototypes had successfully completed ground testing, had survived ejection and vibration tests, and were about to experience first flight tests. GPS TDrop™ is 8.1 inches long, has a circular cross-section of 1.5 inches in diameter and weighs less than a pound. It employs a full GPS engine which is capable of geographic navigation, time capture, and Doppler velocity determination. In addition to gee-location, the other advantage of this approach over the alternative "codeless" technique is maximum potential signal-to-noise ratio for resolving signals from the GPS constellation.

4. **Applications**

Potential applications for TDrop™ technology are wide and varied. The Navy initially plans to use it for determining the temperature and humidity structure in the lowest layers of the atmosphere.

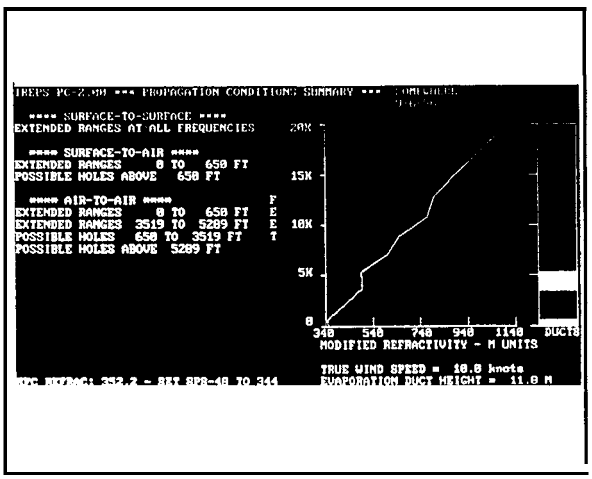

Figure 5.

This will allow them to input high resolution data to mesoscale models and tactical decision aids such as the Integrated Refractive Effects Prediction System (IREPS) as depicted in Figure 5 (Patterson 1990). Other applications include wind profiles for input to computed air release point calculations for precision airdrop operations and atmospheric profiles for input to a number of tactical decision aids and mesoscale models.

An example of the utility of observations such as those obtained from a flexible observing system like the dropsonde, came out of a winter storm reconnaissance effort conducted in the northeast Pacific Ocean during the winters of 1994 and 1995 (Peterman et al 1996). At that time the National Centers for Environmental Prediction (NCEP) (formerly the National Meteorological Center - NMC) cooperated with the US Air Force Hurricane Hunters, the National Weather Service Forecast Office in Seattle, several NOAA Laboratories and Radian to deploy NCAR-designed dropsondes in data sparse areas in the northeast Pacific Basin. WC-1 30 aircraft staged out of McChord AFB WA near Tacoma to areas designated by forecasters in Seattle and NCEP. Areas were agreed upon during teleconference calls between the forecasters and were based on suspected voids in the data base which could adversely affect the numerical model runs. The 1994 deployments identified procedural and technical problems with ingesting asynoptic data such as the dropsondes into the database. The 1995 deployments provided sufficient data and realized significant procedural changes that detailed post analyses of the value of the dropsonde data could be performed. Spearheaded by scientists at NCEP (Lord et al, 1996), ensemble forecasts were assembled with and without dropsonde data. In some cases the dropsonde data had little or no impact on the resulting forecast, but in other cases the data had a significant impact. Figure 6 shows standard deviation of forecast error for the 2-11 Feb 95 period. Dropsonde data had a significant impact on the forecasts valid on 8 Feb.

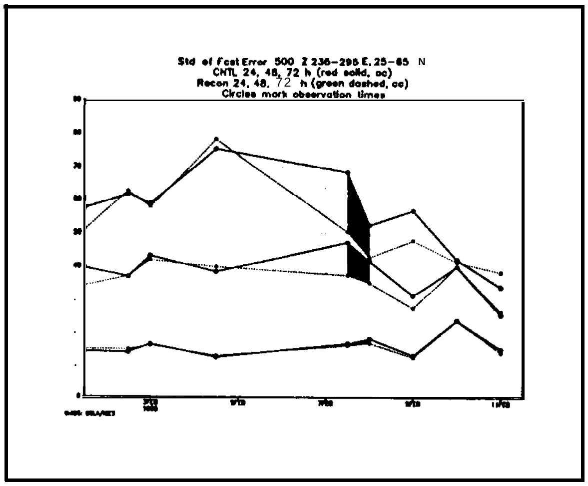

Figure 6.

The analogy for potential TDrop™ operations is that a strategy for when and where tactical dropsondes are employed could be based on similar ensemble techniques. Lord, et al has suggested that the ensembles could be analyzed for suspect areas where accurate data would have the most impact on the forecast some 12-18 hours ahead of when the data are needed. The results of this analysis would then dictate where one would deploy flexible observing assets.

5. **Future Plans**

Following initial flight testing of the GPS TDrop™, a series of demonstrations are planned. One such demonstration anticipates deployment from an SH-60 where several methods for communicating the data are anticipated. Figure 7 illustrates the data flow which allows for transmission of coded data to several locations where they can be decoded and applied in various support scenarios. The key is that the TDrop™ signal is a simple frequency modulation on a selected carrier wave. PTH and GPS information are packed in frames which when demodulated and decoded provide the observed values. Standard sonobuoy frequencies are used for this demonstration but other frequencies in the standard meteorological bands are planned.

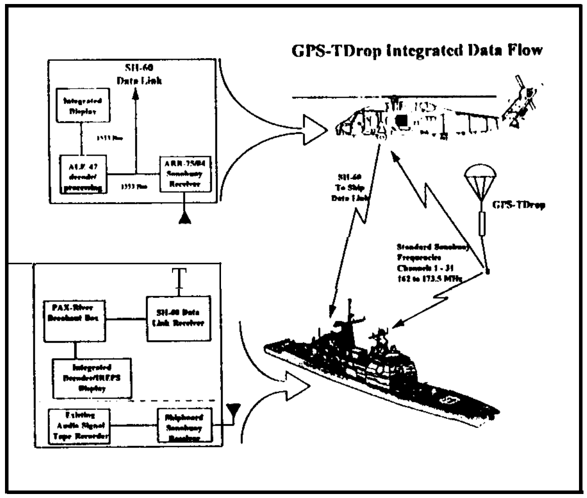

Figure 7.

Another demonstration is planned on the Predator UAV. In this case a special pod is being developed which will house the CMDS as well as the data receiver and GPS initialization unit. Flight tests will demonstrate the ability to warm start the GPS chip in TDrop™ prior to launch. Successful deployment, data reception and relay for operational use will also be demonstrated. Concepts are being developed for operational employment on the Predator UAV while Predator is performing other required tasks without interfering with those tasks.

Since TDrop™ is basically an instrumentation package centered on the GPS engine and its controlling microprocessor, TDrop™ can be the backbone for many other sensor requirements. Figures 8 and 9 depict two such future roles: use as an unattended ground based sensor and as a rocketsonde, respectively. Other concepts on the drawing boards see modified TDrop™ packages as chemical sensors, oceanographic monitors, etc. The key to TDrop™'s utility is its ability to gee-locate itself, determine its own velocity, interrogate multiple on-board sensors, and communicate all of that information over an RF link to a nearby ground or airborne receiver.

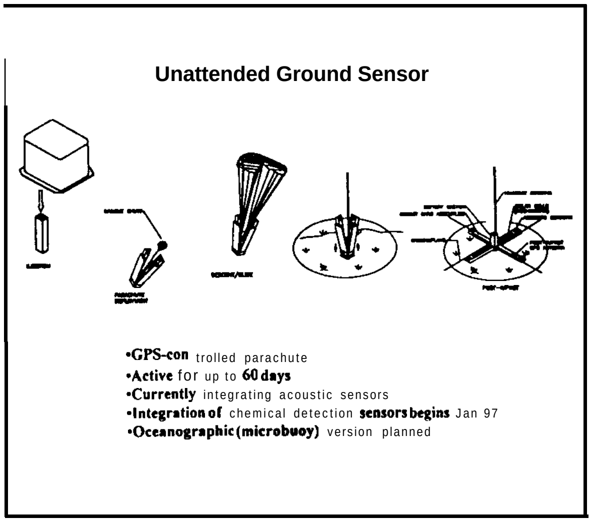

Figure 8.

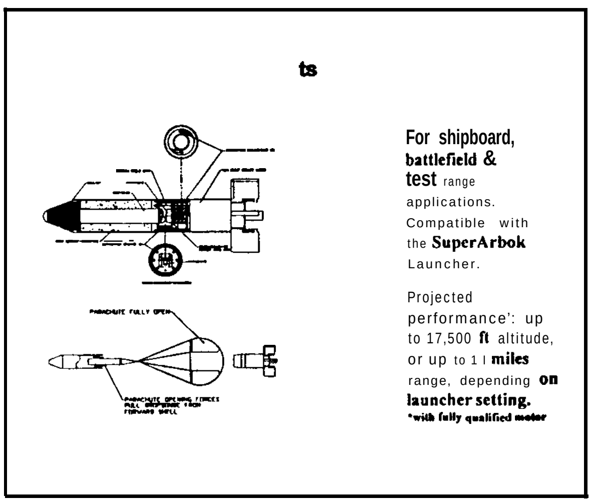

Figure 9.

6. Summary

The US Navy has sponsored a forward looking demonstration of essential atmospheric measurements using GPS technology and standard aircraft CDMS. Operational concepts are being developed which take advantage of the flexibility inherent in a deployable observing system such as TDrop™. Initial prototypes have been successful with future deployments scheduled from SH-60, Predator UAV and other aircraft. Data can be received on board the dispensing aircraft, can be relayed to other sites, or can be monitored by other receivers within line of site of the instrument. The flexibility of the GPS/microprocessor based platform promises a variety of other sensor and employment applications for this technology.

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